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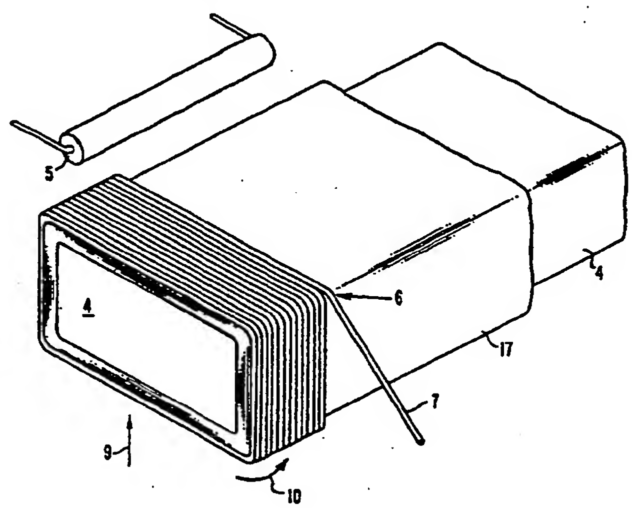
(54) **Method of providing insulation support for electrical conductors, especially in electric coils.**

(57) The invention relates to a method of, generally, providing insulation support for electrical conductors and, more particularly, forming electric coils.

Broadly, the invention resides in applying (at 5) a liquid coating of electrical insulation, preferably unfilled resin; partially polymerizing (at 9) the liquid coating, preferably through irradiation from an ultraviolet source; and applying (at 6) a conductor upon the partially polymerized insulation. This sequence is repeated as often as required to provide a desired number of conductor layers, such as winding layers. The finished product thus formed is subsequently fully cured.



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METHOD OF PROVIDING INSULATION SUPPORT FOR ELECTRICAL CONDUCTORS, ESPECIALLY IN ELECTRIC COILS

This invention relates generally to the art of providing insulation support for electrical conductors and, more particularly, to a method of making electric coils.

In many conventional coils, such as transformer coils, the various conductor or winding layers are supported and insulated from each other by means of cellulosic insulation, such as oil-paper or cardboard, for example. Other conventional coil structures employ non-cellulosic insulating material, such as cast-resin, to provide conductor support and insulation, and these cellulose-free coils have certain advantages over the others insofar as they are more resistant to short circuits, moisture degradation, mechanical vibration, and fire, and less susceptible of out-gassing and thermal aging. Unfortunately, cellulose-free coils of conventional design also have certain drawbacks, chief among them relatively high cost in terms of both manufacture and loadability, and a difficulty of ridding them of shrinkage voids.

It is the principal object of the invention to provide a method which will alleviate these problems heretofore encountered with cellulose-free structures, and the invention, from a broad aspect thereof, accordingly resides in a method of providing insulating support for an

electrical conductor, characterized by the steps of applying a liquid coating of an electrical insulating material upon a substrate, gelling the liquid coating to a firmness sufficient to support an electrical conductor, and applying a conductor upon the gelled insulation.

The above-stated sequence of steps can be repeated as often as required to provide a desired number of conductor layers, in which event a mandrel, an insulated supporting member or a first conductor layer applied upon the insulated supporting member will form the substrate for the first liquid coating of insulating material to be applied and gelled, and each subsequent conductor layer supported by such gelled insulation coating will form the substrate for the next liquid coating of insulation to be applied and gelled.

The term "gelling", as used herein in context with the invention, is intended to mean partially polymerizing to an extent rendering the liquid insulation sufficiently consistent to provide mechanical support for the conductor applied thereupon, but leaving it plastic enough for the conductor to somewhat nest in it and thereby to be held against sliding. Moreover, as liquid insulation coating is applied upon conductor layer and conductor layer is applied upon gelled insulation coating, the conductor layers as well as all conductor portions in each layer become completely insulation-bound and any polymerization shrinkage is accommodated as the insulated structure is being formed, all of which contributes to producing a coil the insulation of which is a homogeneous and essentially void-free mass in intimate physical contact with essentially all surfaces of the winding or windings embedded therein.

IR or UV or EB

The liquid insulating material preferably is gelled through irradiation from a suitable source, such as an infrared or ultraviolet radiation unit or an electron beam unit. At present, ultraviolet radiation is believed to be the most practical and, accordingly, is preferred.

The insulating material may be any suitable cross-linkable liquid resin, such as acrylic epoxy, and preferably is a substantially unfilled resin capable of being instantly gelled through irradiation.

Depending upon such factors as the viscosity of the liquid insulation before gelling, the desired thickness of each finished coating, and the like, the insulation coating upon each substrate (i.e. mandrel, insulating support member or previously applied conductor layer) may be applied as a single-layer coating or it may be formed by applying several thin layers of liquid insulation one upon the other and gelling each such layer before the next one is applied. The viscosity of the liquid insulation should be as low as possible in order to minimize the chance for pockets or voids to develop as the coating is being formed, but it also should be sufficient to minimize undesirable flow of the applied liquid insulation before gelling.

liquid insulat applied

In addition to offering the advantages mentioned hereinbefore, as well as others still to become apparent as the description proceeds, the method according to the invention lends itself admirably well to being applied to the art of coil forming since it permits layer insulation to be formed in situ while the coil structure being built is on a mandrel or coil former and the latter is rotating at commercial winding speeds.

When so employed, the method preferably comprises the step of forming an insulating coating upon the rotating mandrel or coil former by applying thereon liquid insulation in one or several layers and instantly gelling each layer thus applied, and it includes further the steps of winding upon the above-mentioned insulating coating an electric conductor layer, forming upon the latter another gelled insulation coating in the manner set forth above, winding thereon another conductor layer, and so forth until the coil forming operation is completed. After completion of the coil forming operation, the finished

product is subjected to a suitable curing process causing the gelled insulation to set. If desired, provision for cooling ducts can be made during the coil forming operation by introducing, in the liquid insulation, strips of a material which can be subsequently removed from the finished coil, such as polyethylene, for example, which can be melted out with heat suitably applied.

It will be appreciated that a coil formed in accordance with the invention will have a much better conductor space factor than a conventional paper-wound coil, for example. Moreover, the novel coil winding method makes possible a reduction of the conductor mean turn and of the overall coil dimensions (determining the size of the core needed for the coil), it does away with costly coil bonding and drying operations, and it obviates oil impregnation problems since, contrary to conventional insulation systems employing cellulosic material, such as paper, a coil formed in accordance with the invention needs no oil for insulation purposes, all of which tends to lower cost significantly with respect to coil structures of the prior art.

Still another significant advantage derived from the invention in connection with coil winding has to do with insulation grading. It is known that when an electrical winding is formed from wire wound helically about the coil axis alternately back and forth between the opposite coil ends so as to form consecutive layers of conductor turns, the dielectric stress from layer to layer is relatively low at the mutually connected ends of any two adjacent turns layers and gradually increases toward the mutually non-connected ends of such turns layers. With conventional coil structures having winding or turns layers spaced apart uniformly for the whole length, i.e. axial dimension, of the coil, the overall coil size is determined by the thickness which the insulation between turns layers must have in order to withstand the highest dielectric stress therebetween, that is, it is determined

by the thickness of insulation needed at the non-connected ends of the turns layers.

The method according to the invention allows the total volume of the insulation and, hence, the total coil size to be considerably reduced in a facile manner by grading the insulation during coil winding, that is, by varying the thickness of insulation between adjacent winding layers in accordance with the changing dielectric stress therebetween.

In a preferred embodiment of the invention, such graded insulating coating is formed upon a conductor-turns layer, or winding portion, of the coil structure by applying and instantly gelling, as the coil structure is being rotated, layer upon layer of liquid insulation in a manner such that the width of the various layers, as measured across the underlying winding portion from the end thereof which will be the high-stress end with respect to the conductor-turns layer or winding portion to be formed next, changes incrementally from insulation layer to successive insulation layer so that the resulting insulating coating will have a wedge-like or tapered cross-section, that is, will be graded, its thickness being maximal at the high-stress end and decreasing gradually toward the low-stress end of the underlying winding portion thus coated.

The incremental change in the width of successively applied insulation layers is achieved through axial relative displacement effected between the insulation applicator and the coil structure as the latter is being rotated.

In another embodiment of the invention, a graded insulating coating is formed on a conductor-turns layer of the coil structure by applying, and gelling, a single layer or coat of liquid insulation extruded through a nozzle shaped to impart to the extruded layer of insulation either the desired wedge-shaped cross-section or a rectangular cross-section which then is re-shaped, e.g. by

means of a wiper, such as a rubber blade or the like, to assume the desired wedge-like cross-sectional configuration.

Preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional partial view of an electric coil made in accordance with the prior art;

Fig. 2 is an isometric view schematically illustrating a manner of making an electric coil in accordance with a preferred embodiment of the invention;

Fig. 3 is a sectional view taken along line II-II of Fig. 4;

Fig. 4 is an isometric view of the nearly finished coil;

Fig. 5 is a cross-sectional partial view of an electric coil having graded insulation formed in accordance with the invention;

Fig. 6 is an isometric view schematically illustrating one manner of forming layer insulation in a coil such as shown in Fig. 5;

Fig. 7 is an enlarged, fragmentary sectional view illustrating in greater detail how insulation grading is achieved by the method of Fig. 6;

Fig. 8 is a cross-sectional partial view similar to Fig. 5 and showing an electric coil with graded insulation formed in a manner as illustrated in Figs. 9 to 15 or Figs. 16 to 20;

Figs. 9, 10 and 11 are fragmentary end views illustrating successive stages of applying insulation in forming the coil of Fig. 8;

Figs. 12, 13 and 14 are cross-sectional views taken along lines XII-XII, XIII-XIII and XIV-XIV of Figs. 9, 10 and 11, respectively;

Fig. 15 is an isometric and partly sectional view showing how a graded coating of liquid insulation is applied upon a layer of conductor turns in making the coil of Fig. 8;

Fig. 16 is a sectional view illustrating a somewhat different manner of forming graded insulation;

Fig. 17 is a cross-sectional view taken along line XVII-XVII of Fig. 16;

Fig. 18 is a sectional view showing a modification of the method of Fig. 16;

Fig. 19 is a cross-sectional view taken along the line XIX-XIX of Fig. 18; and

Fig. 20 is a view similar to Fig. 19 but showing the coil in a more advanced coil forming stage.

Referring now to Fig. 1 of the drawings, it shows part of a conventional transformer coil, still on a coil forming mandrel 4, in which layers 3a, 3b and 3c of conductor turns, forming part of a winding of the coil, are supported and insulated from each other by cellulosic insulation in the form of paper wraps or cardboard tubes 2a, 2b and 2c. Typically, such coil is formed in successive steps by applying the first wrap or tube of cellulosic insulation 2a upon the mandrel 4, then winding thereon the first layer 3a of turns from one end of the coil to the other, as indicated by the lowermost arrow in Fig. 1, thereafter applying the second wrap or tube 2b of insulation upon the turns layer 3a, then winding thereon the second layer 3b of turns in the opposite direction, and so forth until the coil is finished.

As distinct therefrom, Fig. 2 schematically illustrates a method of making a cellulose-free coil, such as shown in Figs. 3 and 4, in accordance with the invention. In Fig. 2, reference numeral 4 again designates a mandrel, numeral 5 refers to an applicator, such as a paint roller, numeral 6 designates a winding station, numeral 7 indicates a conductor, such as enamelled copper wire, numeral 9 designates a gelling station, numeral 10 indicates the direction in which the mandrel 4 with the coil structure thereon is rotated during a coil forming operation, and numeral 17 indicates an insulating coating applied by means of the applicator 5. As mentioned here-

inbefore, the gelling station 9 may comprise any suitable radiation source, such as an infra-red or ultraviolet or electron beam unit, but preferably comprises an ultraviolet radiation source.

Fig. 2 shows the coil forming operation at an advanced stage. From Fig. 3 it is seen that the whole coil forming operation of this embodiment comprises the steps of providing an insulating substrate 13 upon the mandrel 4; forming upon the substrate 13 a first, e.g. low-voltage, winding by applying, as the mandrel is turning, several layers 15 of insulated, e.g. enamelled, conductor strip first upon the insulating substrate 13 and then one upon the other; forming a gelled insulating coating 17 upon the winding 15; helically winding, as shown in Fig. 2, preferably insulated, e.g. enamelled, conductor wire 7 upon the gelled coating 17 from one coil end to the other so as to form a layer of conductor turns 19 as part of a second, e.g. high-voltage, winding; forming a gelled insulating coating 21 upon this turns layer 19; helically winding upon the coating 21 a layer of turns 23 from the same wire as above but proceeding in the opposite axial direction; and covering the turns layer 23 with an insulating coating 25, preferably likewise gelled. The insulating coatings 17, 21 and 25 are shown in Fig. 3 as forming overlaps 17', 21' and 25', respectively, which cover the edges of the respective underlying winding 15 and winding layers 19, 23 at both ends of the coil so as to provide maximum protection from arc-overs between the edges of adjacent windings or winding portions.

The substrate 13 on the mandrel 4 may be a tubular member preformed from a suitable resinous material and slipped onto the mandrel or it may be an insulating coating formed in the same manner as the coatings 17 and 21 and, preferably, also the coating 25, namely by applying the insulating material as a viscous liquid by means of the applicator 5 (Fig. 2), and instantly gelling the applied liquid insulation through irradiation received as

it is being carried past the gelling station 9 by the mandrel 4 rotating in the direction of the arrow 10.

The thickness of each insulation coating 13, 17, 21 or 25 may vary, depending upon such parameters as the required insulating or dielectric strength of the coating, its mechanical strength, and the like; and the various coatings may be formed as single-layer coatings or as multi-layer coatings, depending upon overall coating thickness desired, the viscosity of the liquid insulation to be applied, coil winding speed, and the like.

A multi-layer coating is formed, as the mandrel 4 is turning, by applying several relatively thin layers of liquid insulation one upon the other by means of the applicator 5, and instantly gelling them at the gelling station 9, one such liquid layer of insulation being applied and gelled during each revolution of the mandrel. For instance, there may be 5 to 10 liquid layers, each about 40 mils (1.0 mm) thick, wound upon each other and resulting in a coating having a thickness of about from 0.2 to 0.4 inch (5.0 to 10.0 mm), or there may be 30 to 50 liquid layers, each about 4 mils (0.1 mm) thick, wound upon each other and resulting in a coating having a thickness of from 0.1 to 0.2 inch (3.0 to 5.0 mm).

Building up such insulating coating from thin layers of liquid insulation each wound upon the other and instantly gelled offers a significant advantage insofar as the liquid insulation thus applied in thin layers will readily flow into and thus eliminate any spaces between adjacent conductor portions, and any holes and voids, and will completely cover and effectively isolate small contaminants such as might be present and as would reduce the breakdown strength of the finished coating. Of course, even though the insulation is applied layer upon layer, it will be understood that applying it as a liquid and just gelling, instead of curing, the latter before the next layer is applied will yield a coating that is not stratified but is dense and homogeneous. Thus, the term "multi- "geschichtet"

layer" used herein as part of the expression "multi-layer coating" is to be construed as referring to the manner of applying the coating and not to the structure of the finished coating.

If desired, extra insulation can be provided between the conductor-strip layers 15 of the first winding by applying to the pre-insulated conductor strip, as it is being wound in place, a liquid layer of insulation by means of the applicator 5 (Fig. 2), and instantly gelling the liquid layer, thus applied, through irradiation received at the gelling station 9.

It should be noted also that even though the first winding is shown in the embodiment of Fig. 3 as wound spirally, i.e., as layer-wound, from conductor strip, it could be formed from a conductor wire wound helically in a similar manner as shown in Fig. 2; and that, furthermore, the second winding, although shown herein as helically wound from wire, could be formed from conductive strip material layer-wound in a similar manner as the first winding 15 of the illustrated embodiment. Of course, the particular number of conductor layers 15 and turns layers 19, 23 employed in this embodiment likewise must not be considered as limiting, having regard to the scope of the invention.

The insulation overlaps 17', 21' and 25' may be formed independently of the respective coatings 17, 21, 25 by applying insulation to the opposite edges of the winding 15 and each turns layer 19 or 23 as the winding or turns layer is formed, and instantly gelling the applied edge insulation in a similar manner as explained in connection with the insulating coatings.

As an alternative which may be preferred, the overlaps, such as 17', 21' and 25' can be formed concurrently with the respective insulating coatings 17, 21 and 25, simply by applying an excess of insulation beyond the opposite edges of the associated winding or turns layer and lapping it, the overlaps thus formed being gelled, of course, together with the remaining part of the coating.

As seen from Figs. 3 and 4, provision for cooling ducts can be readily made by winding into the outer insulating coating 25 a strip or strips 35 of a suitable material which can be removed when the coil structure is complete. Thus, with the coating 25 formed to part of its desired thickness, the strips 35 are put in place thereon at the desired locations and then are covered with more insulation as the mandrel 11 continues to rotate. When the coil winding operation is finished and the coil structure is complete, the strips 35 are removed to leave ducts for cooling liquid, such as transformer-oil, to pass therethrough. A suitable material of which the strips 35 may be made is polyethylene which can be melted out, subsequently, e.g., by electrically energizing the finished coil prior to immersing it in a coolant.

Referring now to Figs. 5, 6 and 7 of the drawings which are partial views of an electric coil formed with graded insulation in accordance with the invention, Fig. 5 shows the coil, mounted on a mandrel 4, as comprising conductor turns layers 29a, 29b and 29c forming portions of an electric winding, an insulating substrate or base coating 27a on the mandrel, graded insulating coatings 27b and 27c, and an insulating coating 34. The conductor-turns layers 29a-c, wound from a single conductor 7 (Fig. 6), such as copper wire, are interconnected at the thinner ends of the graded insulating coatings 27b and 27c therebetween to form a complete winding. It will be appreciated, of course, that the invention is not limited to the three winding portions and four insulating coatings shown in this embodiment, the number of windings and winding portions, and consequently the number of insulating coatings, depending in each case upon the kind of coil desired.

Fig. 6 illustrates a method of forming a coil such as shown in Fig. 5. Except for the step of insulation grading, this method is similar to the one previously described herein in connection with forming insulation

coatings from several gelled liquid layers of insulation applied one upon the other, and the same reference numerals are used in Fig. 6 as in Fig. 2 to indicate similar elements performing corresponding functions, such as the coil former or mandrel 4, the insulation applicator 5, and the gelling station 9. The inner and outer insulating coatings 27a and 34 of the coil shown in Fig. 5 are of substantially uniform thickness throughout, and they can be formed in the same manner as hereinbefore set forth in connection with the previously described embodiment. The following description will be limited to the manner of forming graded insulation coatings, such as the coatings 27b and 27c.

Referring in this context to Fig. 6 which shows the coil forming operation at a stage where the turns layer 29a is wound in place upon the insulating coating 27a and the insulating coating 27b is applied upon the turns layer 29a, it will be seen therefrom that provision is made in this embodiment for axial relative displacement to occur between the insulation applicator 5 and the coil structure as the liquid insulation is being applied. More specifically, the applicator 5 is seen as advancing in the same axial direction as the conductor-turns winding operation, with the result that, during each revolution of the coil former 4, the applicator 5 applies a liquid layer of insulation (instantly gelled at 9) to cover the whole of the previously applied and gelled layer and, in addition, at least one still exposed conductor turn of the turns layer 29a. This procedure is graphically illustrated in Fig. 7 wherein the lines, such as lines $27b_1$ and $27b_2$, represent the various layers of liquid insulation applied and gelled individually, albeit preferably in one continuous operation. Of course, it will be appreciated that, even though the width of the successively applied layers in this embodiment is shown as incrementally increasing (because the applicator 5 is assumed to advance from left to right, as viewed in Figs. 6 and 7), it would incremen-

tally decrease if the applicator 5 first applied liquid insulation to cover the whole width of the underlying conductor-turns layer, and then advanced toward the left.

Upon the insulating coating 27b thus formed, the wire 7 is wound, starting at the thin end and proceeding towards the thick end of the coating, to form the turns layer 29b, upon which the graded insulating coating 27c then is formed in the same manner as described with respect to the coating 27b, but with the axial relative motion between the applicator 5 and the coil structure reversed in order to form the coating 27c with a reverse taper, having regard to the previously formed coating 27b.

Next, the conductor-turns layer 29c is wound in place upon the gelled coating 27c, and then the insulating coating 34 is formed on the turns layer 29c, preferably by means of the same applicator 5, however arrested in its axial movement and applying several layers of liquid insulation one upon the other and all of them over the full width of the coil, as the latter is turning.

It will be appreciated that alternate insulating coatings, such as coatings 27a-c and 34, and conductor-turns layers, such as layers 29a-c, can be formed, according to the invention, in one substantially continuous winding operation. Furthermore, it will be clear from the above that the volume of insulation in a coil formed as described above will be only about half the volume of a similarly rated coil formed in accordance with conventional practice, such as shown in Fig. 1, and in which the insulating layers between conductor-turns layers are of uniform thickness determined by the region of maximum dielectric stress.

Turning now to the next embodiment of the invention, Fig. 8 shows, as mounted on a mandrel or coil former 4 having end flanges 60 and 62, a coil structure which is similar to the one of Fig. 5 in that it, too, comprises conductor-turns layers 44a, 44b, 44c, an insulating base coating or substrate 42a, an insulating outer coating 50,

and graded insulating coatings 42b and 42c which are relatively thick at one end, such as at 68 or 76, respectively, and relatively thin at the other end, such as at 70 or 78, respectively.

The coil structure of Fig. 8 differs from the one of Fig. 5 by the manner in which its insulating coatings are formed or, rather, the kind of applicator employed in applying them. Referring in this context to Figs. 9 to 15, Fig. 9 shows the base coating 42a as being applied upon the mandrel 4 from a nozzle 54 which has a rectangular cross-section (Fig. 12), and from which liquid insulating material 42, preferably a cross-linkable viscous resin, is extruded onto the surface of the mandrel 4 as the latter is turning in the direction of the arrow 10. The insulating material, as extruded, is assumed in this embodiment to be thick enough to form the coating 42a having the required thickness with one complete turn of the mandrel, whereupon the material 42 is severed at the nozzle so that the leading and trailing ends of the viscous liquid layer thus applied will abut and merge in each other so as to form a continuous coating 42a. Of course, here again the viscosity of the resin 42 extruded from the nozzle 54 is chosen such as to minimize undesirable flow of the resin until it is gelled at the gelling station represented by the ultra-violet radiator 58.

Onto the gelled insulating coating 42a, a conductor, e.g., enamelled wire, is wound from left to right, as viewed in Fig. 8, to form the turns layer 44a upon which the insulating coating 42b then is applied, as seen from Fig. 10, in a similar manner as described above in connection with the coating 42a. However, now a nozzle 64 is being used which has a generally triangular or trapezoidal opening 66 (see Fig. 13) which imparts to the insulating material 42 extruded therethrough the desired tapered or wedge-like cross-sectional configuration to grade the coating 42b so that it is relatively thick, as at 68, at one end and relatively thin, as at 70, at the

other. The isometric view of Fig. 15 shows in greater detail how the dielectric material 42 is extruded from the nozzle 64 and onto the conductor-turns layer 44a with which it is shown to be substantially coextensive. Of course, this single-layer insulating coating 42b also is instantly gelled by radiation from the source 58 (Fig. 10) as the rotating mandrel 4 is carrying it therepast.

With the mandrel 4 continuing to rotate, the conductor-turns layer 44b is wound upon the graded and gelled insulating coating 42b from right to left, as viewed in Fig. 8, whereupon a nozzle 72 (Fig. 11) for applying the insulating coating 42c is brought into position. This nozzle 72 has a generally triangular or trapezoidal opening 74 (Fig. 14) just like the opening of the nozzle 64 but 180° displaced relative thereto so that the coating 42c, when applied, likewise will have its relatively thick end or edge 76 disposed where the dielectric stress between the turns layers 44b and 44c is greatest, and will have its thin end or edge 78 disposed where the dielectric stress between is low. The winding operation continues, with the turns layer 44c being wound in place upon the gelled coating 42c from left to right, as viewed in Fig. 8.

It will be understood that additional conductor-turns layers and graded insulating coatings may be applied, if required, but for the purpose of illustration it is assumed that the layer 44c completes the electric winding and is covered with an insulating coating, i.e., coating 50, which is applied in a similar manner as the base coating 42a, namely, by extruding it from the rectangular nozzle 54 shown in Fig. 12. Of course, each insulating coating is gelled as it passes through the gelling station represented by the ultra-violet radiator 58.

Another method of achieving insulation grading is shown in Figs. 16 and 17, wherein all insulating coatings are applied by extrusion from the nozzle 54 with the rectangular openings, and the coatings 42b and 42c are

graded by means of a scraper or blade 80 disposed at an appropriate angle or having a beveled cutting edge 82 to trim the extruded viscous material 42 into the desired triangular or trapezoidal cross-sectional shape by removing the excess material, as indicated at 84.

Figs. 18, 19 and 20 show an arrangement which is very similar to the one in Figs. 16 and 17, except that the blade 80 and, consequently, the gelling station 58 are spaced farther from the nozzle 54 circumferentially about the coil structure, having regard to the rotational direction 10 of the mandrel 4, and that Fig. 20 shows the electric winding as comprising only two turns layers 44a and 44b instead of three, as shown in Fig. 8, and with the layer 44b sloping and covered with an insulating coating 92 which has a tapered cross-section to adapt to the slope of the turns layer 44b and to uniform outer coil dimension.

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What we claim is:

1. A method of providing insulation support for an electrical conductor, characterized by the steps of applying a liquid coating of electrical insulation upon a substrate, gelling the liquid coating to a firmness sufficient to support a conductor, and applying a conductor upon the gelled coating.

2. A method according to claim 1, characterized in that said gelled coating is formed by applying and gelling a plurality of thin liquid layers of insulation one upon the other.

3. A method according to claim 1 or 2, characterized in that said steps are reiterated, in the sequence stated, to provide insulation support for several conductor layers each of which is applied upon the preceding gelled coating of insulation and serves as a substrate for the succeeding liquid coating to be applied and gelled.

4. A method of forming an electric coil structure, characterized by the steps of applying a liquid coating of electrical insulation upon a substrate, instantly gelling the liquid coating to a firmness sufficient to support a conductor, and winding a conductor upon the gelled coating.

5. A method according to claim 4, characterized in that said gelled coating is formed by winding and gelling a plurality of thin liquid layers of insulation one upon the other.

6. A method according to claim 4 or 5, characterized in that said conductor is a pre-insulated strip-like conductor wound spirally upon said gelled coating.

7. A method according to claim 4, characterized in that said conductor is a strip-like conductor, and that the liquid coating of insulation is applied to the strip-like conductor, and is instantly gelled, as the conductor is being wound spirally in place.

8. A method according to claim 4, characterized in that said conductor is a wire wound helically upon said gelled coating.

9. A method according to claim 8, characterized in that said steps are reiterated, in the sequence stated, in such manner that the steps of applying and gelling each liquid coating, except a final one, are followed by a step of helically winding a layer of turns from said wire upon the gelled coating, and each step of winding such layer of turns is followed by the steps of applying upon the latter, and of instantly gelling, a liquid coating of insulation.

10. A method according to claim 9, characterized in that successive layers of turns are alternately wound axially in opposite directions such that each turns layer intermediate two other turns layers is directly connected at one end to the preceding turns layer and, at its opposite end, is connected to the next-following turns layer, the gelled liquid coating of insulation between each pair of adjacent turns layers being applied in such manner as to have a thickness which gradually increases from the directly connected ends of said adjacent turns layers toward the separated ends thereof.

11. A method according to claim 10, characterized in that the gelled coating between each pair of adjacent turns layers is formed by applying and instantly gelling liquid layer of insulation upon liquid layer in a manner such as to cause the width of the individual insulation layers, as measured from the separated ends of the adjacent turns layers towards the connected ends thereof,

to change incrementally from insulation layer to successive insulation layer.

12. A method according to claim 11, characterized in that said liquid layers are applied by means of an applicator, and are instantly gelled, simultaneously with rotating the coil and with effecting axial relative movement between the latter and the applicator.

13. A method according to claim 4, 8, 9 or 10, characterized in that said liquid coating of insulation is extruded from a nozzle.

14. A method according to claim 13, characterized in that said nozzle has an opening shaped to correspond to the desired cross-section of the applied coating of insulation.

15. A method according to any one of the claims 4 to 14, characterized in that liquid overlaps of said insulation are formed and instantly gelled upon the axially outer edges of each winding formed from the conductor.

16. A method according to any one of the claims 4 to 15, characterized by the steps of introducing, in the applied insulation, strips of a material capable of being subsequently removed, and of removing said strips upon completion of the coil structure to form cooling ducts in the insulation.

17. A method according to claim 16, characterized in that said material is polyethylene, and that said strips are melted out of the insulation through the application of heat.

18. A method according to any one of the claims 4 to 17, characterized in that the liquid insulation is applied and instantly gelled, and the conductor is wound in place, in a substantially continuous winding operation during which the coil structure is repeatedly rotated sequentially past an insulation applicator, a gelling station, and a conductor winding station.

19. A method according to any one of the preceding claims, characterized in that said insulation is a cross-linkable liquid resin.

20. A method according to claim 19, characterized in that said liquid resin is an unfilled resin and is instantly gelled through irradiation.

21. A method according to any of one of the preceding claims, characterized in that the liquid insulation is applied having a viscosity just high enough to prevent undesirable flow of the applied liquid insulation before gelling.

22. An electric coil structure having at least one electric winding supported in cellulose-free insulation, characterized in that said insulation is a homogenous essentially void-free mass of substantially unfilled resin.

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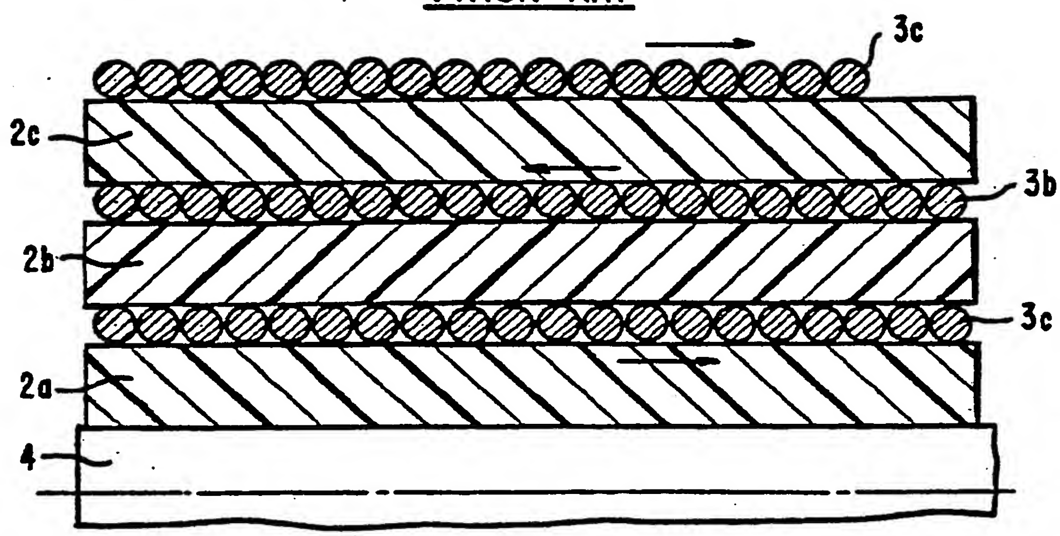
FIG. 1.

PRIOR ART



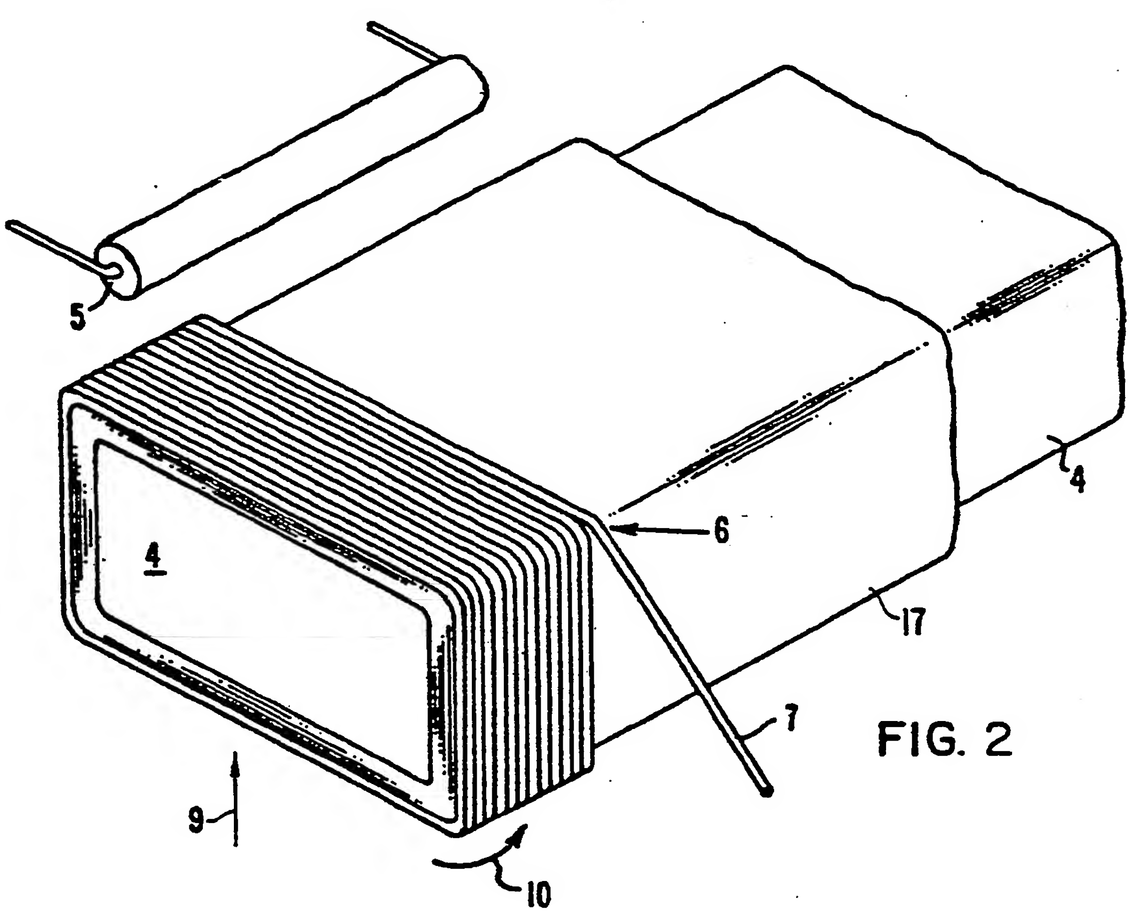


FIG. 2

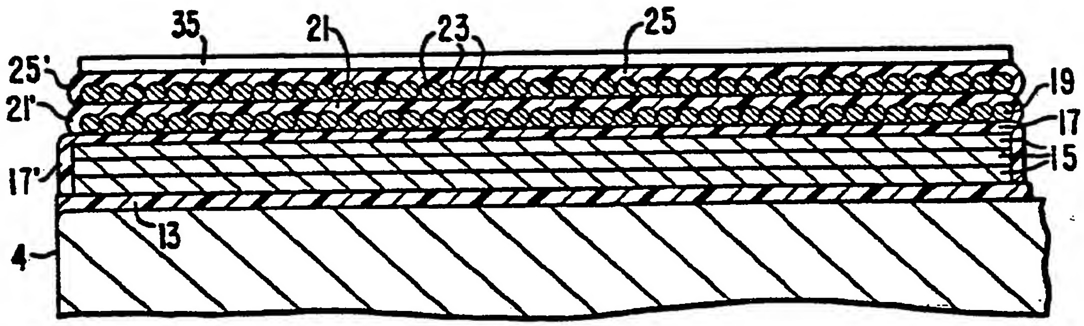


FIG. 3

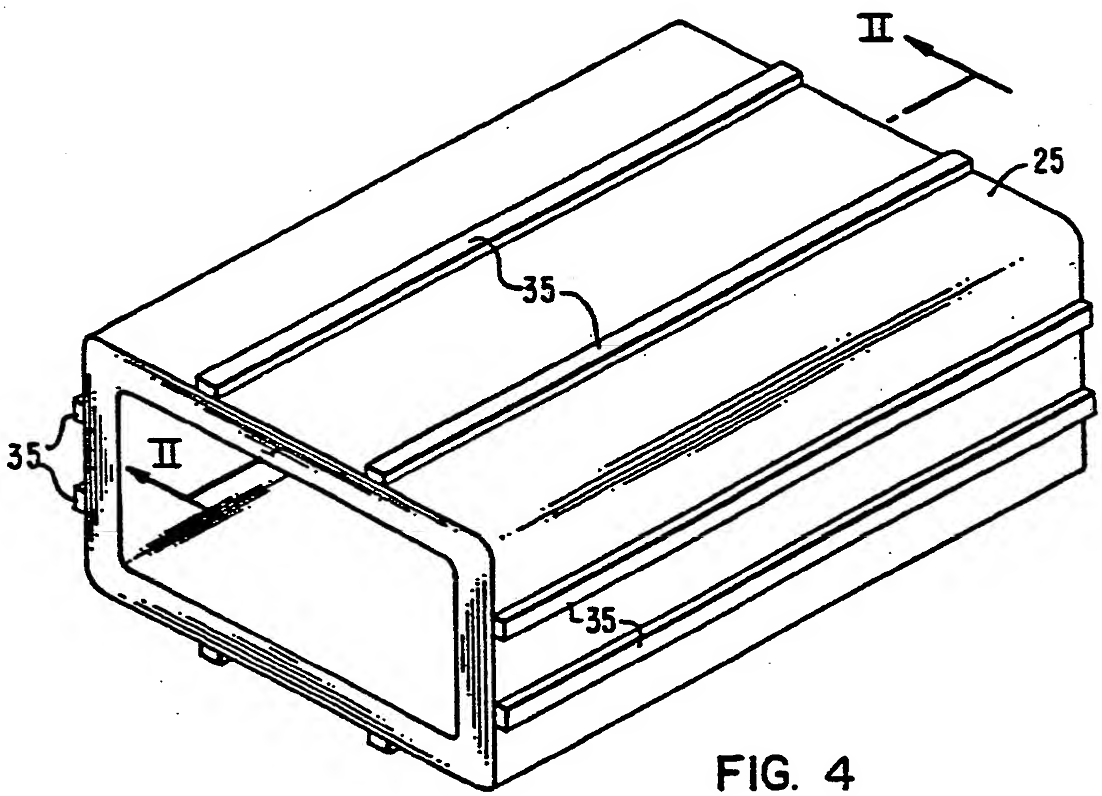


FIG. 4

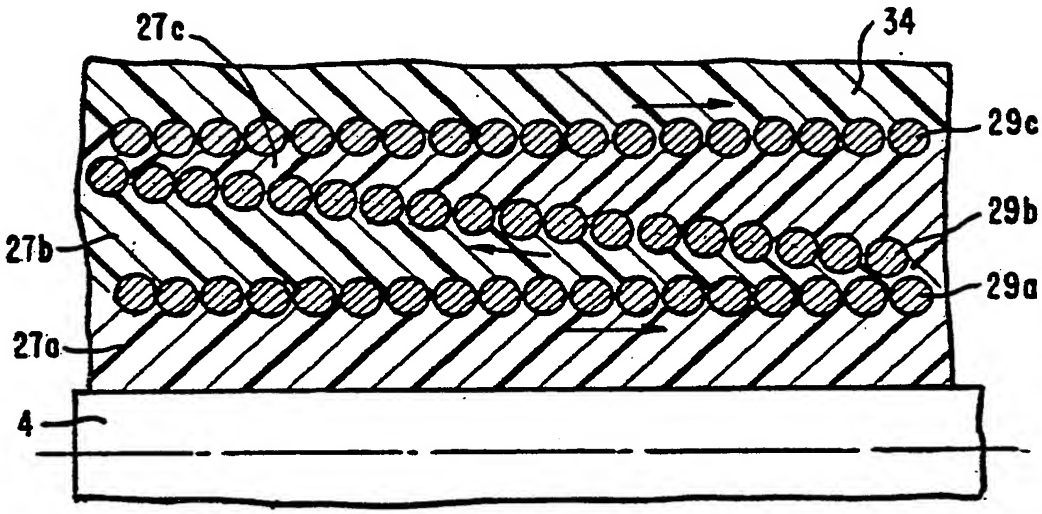

27c
34
29c
29b
27b
29a
27a
4

FIG. 5

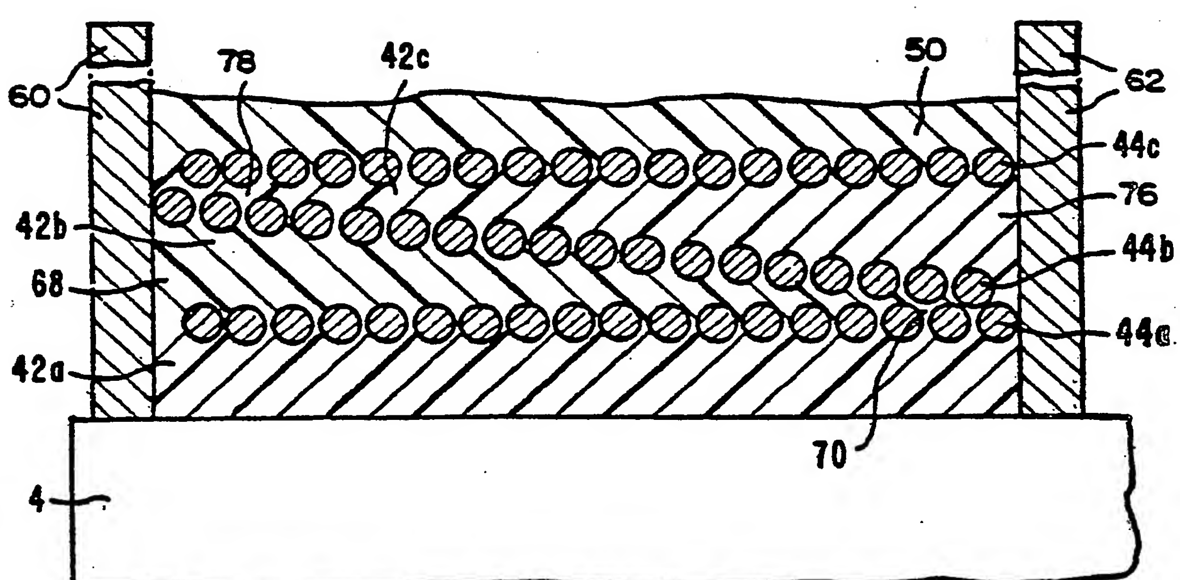

78
42c
50
60
62
44c
76
42b
44b
68
44a
42a
70
4

FIG. 8

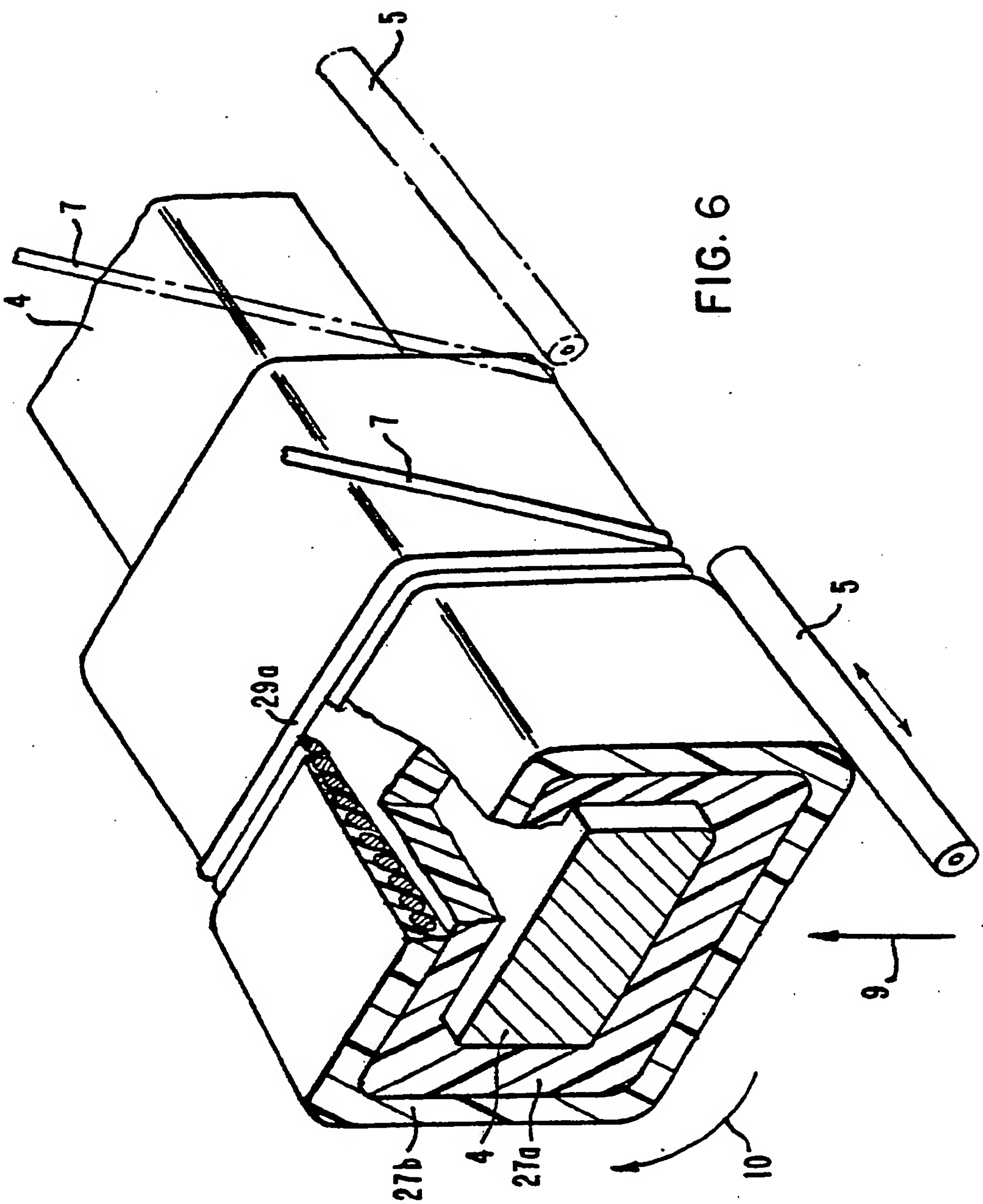


FIG. 6

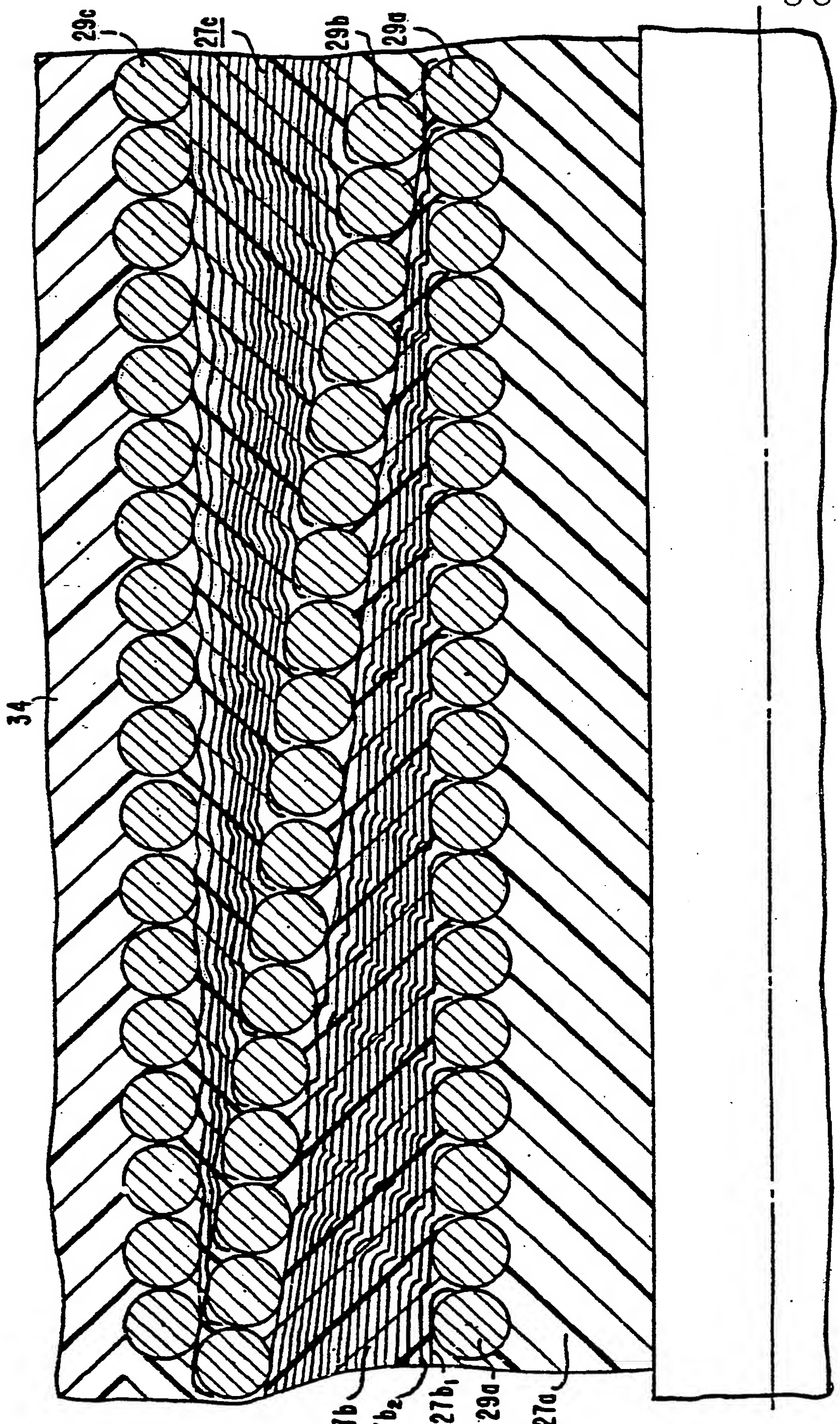


FIG. 7

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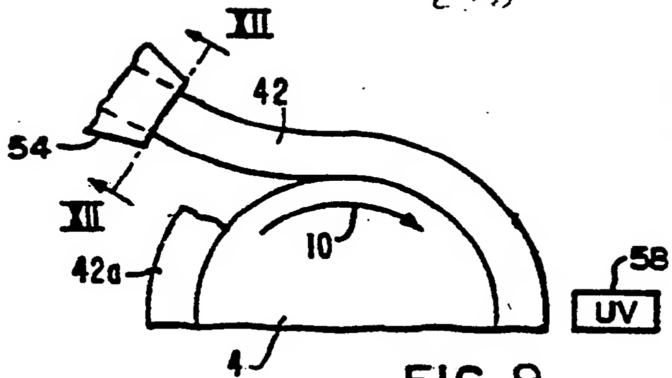

FIG. 9

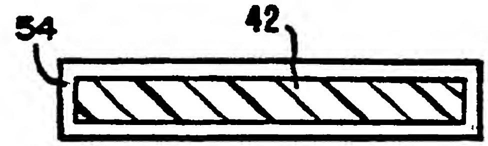

FIG. 12

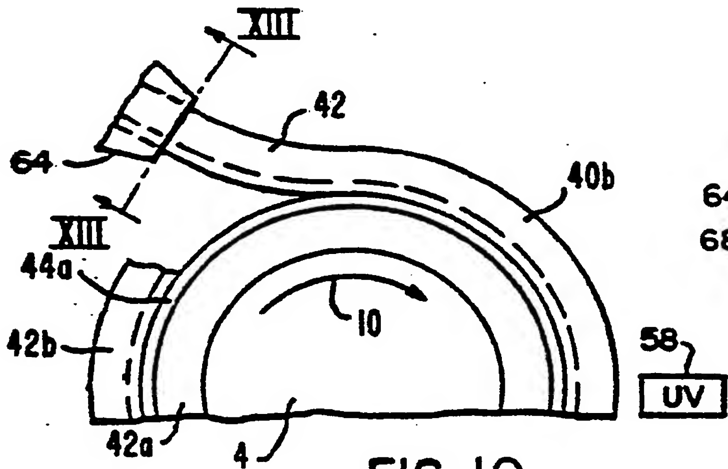

FIG. 10

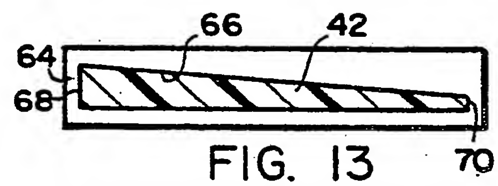

FIG. 13

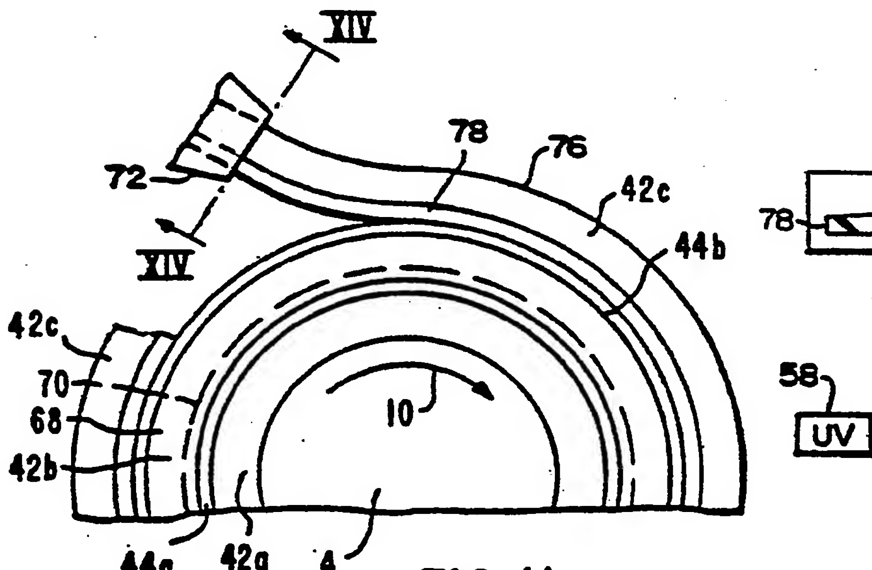

FIG. 11

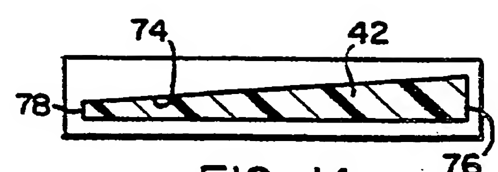

FIG. 14

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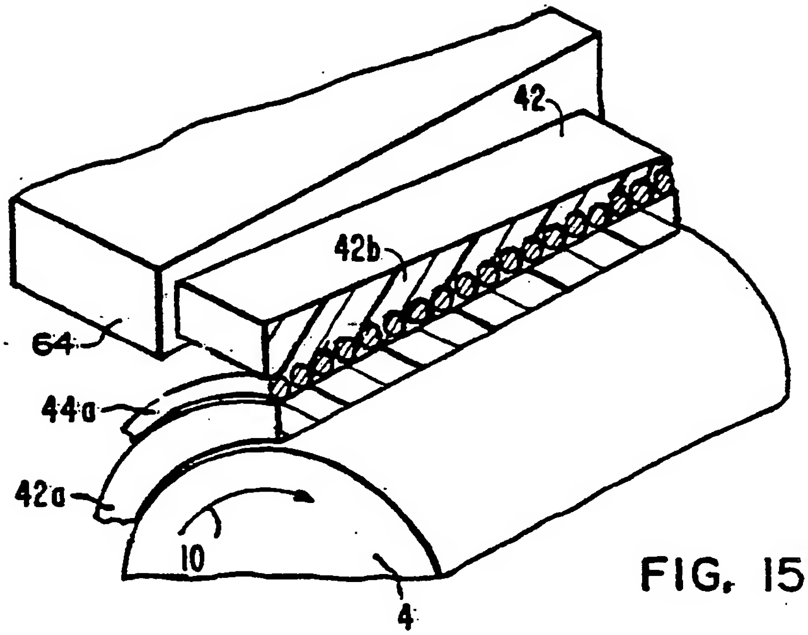

FIG. 15

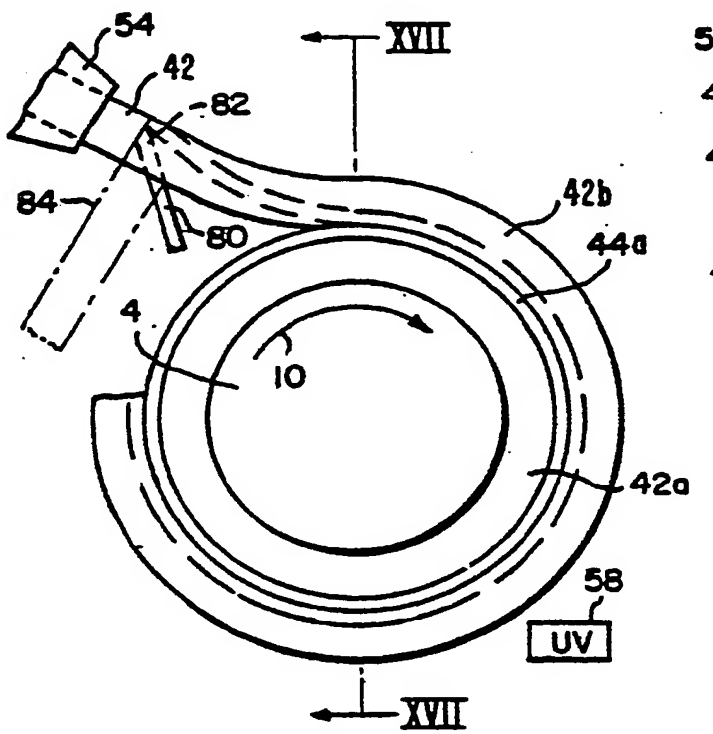

FIG. 16

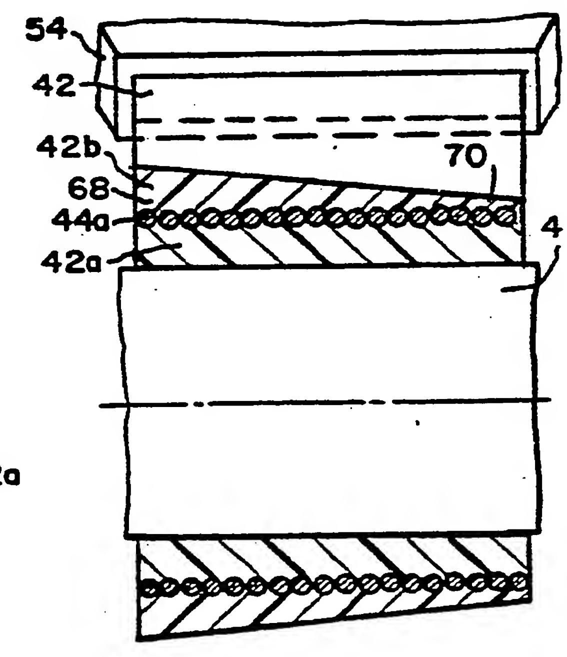

FIG. 17

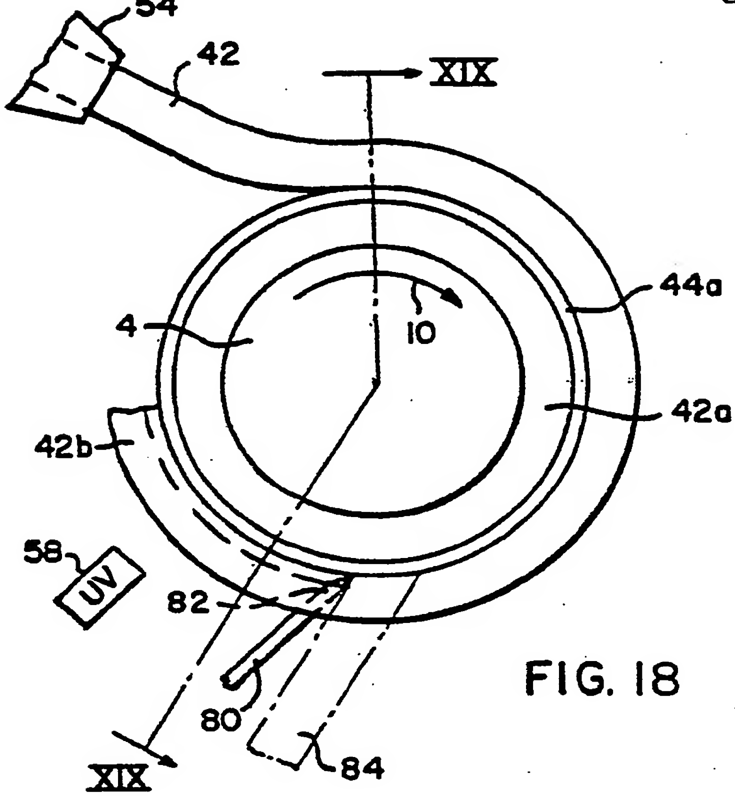

FIG. 18

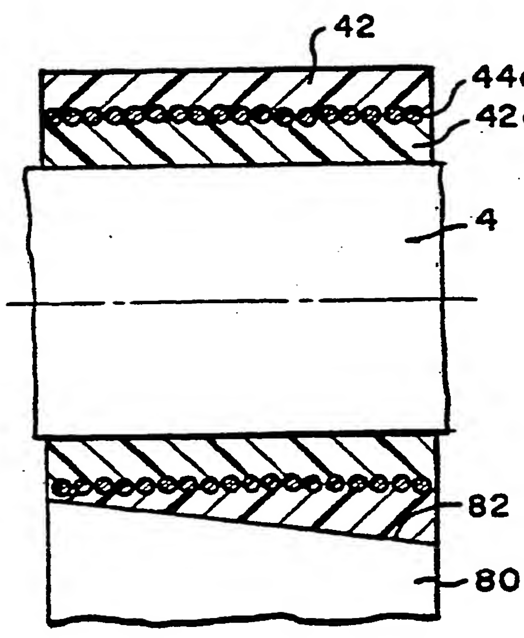

FIG. 19

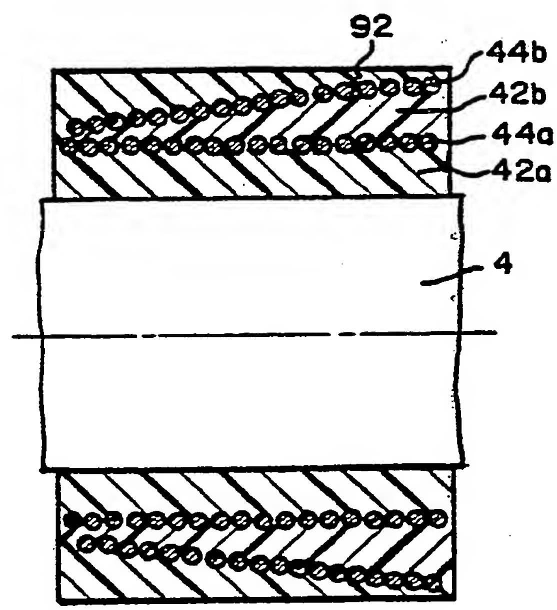

FIG. 20

European Patent Office

EUROPEAN SEARCH REPORT

0065147

Application number

EP 82103646.4

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	DE - A1 - 2 924 191 (TRANSFORMATOREN UNION) * Claims 1,5 *	1,3,4, 8,9,19 21,22
	DE - C - 665 834 (KOCH)	
X	* Page 2, lines 72-120; fig. 3-7 *	1-5,7, 15,19, 21,22,
Y	* Page 2, lines 72-120; fig. 3-7 *	6,8-11 13,14, 18,20
Y	AT - B - 205 586 (B.B.C.) * Page 1, line 29 - page 2, line 7; fig. *	8-10, 13,14
	DE - C - 610 043 (A.E.G.)	
X	* Page 2, lines 42-117; fig. 1,2 *	1-5,8, 9
Y	* Page 2, lines 42-117; fig. 1,2 *	6,10, 11,18
	US - A - 4 239 077 (DIXON et al.)	
Y	* Abstract *	20
A	* Column 1, lines 1-51; column 4, line 44 - column 5, line 32 *	1

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

H 01 F 41/12
H 01 F 5/06

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

H 01 F 41/00
H 01 F 5/00
H 01 F 27/00
H 02 K 15/00
H 02 K 3/00
H 01 B 13/00
H 01 B 7/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
Y: particularly relevant if combined with another document of the same category
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: earlier patent document, but published on, or after the filing date
D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	03-08-1982	KUTZELNIGG